

Argonne National Laboratory

Energy and Environmental Systems Division

1981 Research Review

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Energy and Environmental Systems Division

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Argonne National Laboratory

Argonne National Laboratory, one of the nation's leading energy research centers, develops and assesses nuclear and alternative energy systems and conducts a broad range of programs in the physical, environmental, and biomedical sciences. Argonne is operated by the University of Chicago and the Argonne Universities Association under contract to the U.S. Department of Energy. The Laboratory's fiscal 1981 operating budget, received from a variety of government agencies, was \$267 million; its capital assets exceeded \$545 million. Argonne employs some 4300 persons, of whom about 1600 are scientists and engineers. Use of the facilities and equipment described herein for private purposes or foreign programs requires prior approval.

Energy and Environmental Systems Division

To effectively manage the nation's energy and natural resources, government and industry leaders need accurate information regarding the performance and economics of advanced energy systems and the costs and benefits of public-sector initiatives. The Energy and Environmental Systems Division (EES) of Argonne National Laboratory conducts applied research and development programs that provide such information through systems analysis, geophysical field research, and engineering studies. During 1981, we:

- Analyzed the production economics of specific energy resources, such as biomass and tight sands gas.
- Developed and transferred to industry economically efficient techniques for addressing energy-related resource management and environmental protection problems, such as the reclamation of strip-mined land.
- Determined the engineering performance and cost of advanced energy-supply and pollution-control systems.
- Analyzed future markets for district heating systems and other emerging energy technologies.
- Determined, in strategic planning studies, the availability of resources needed for new energy technologies, such as the imported metals used in advanced electric-vehicle batteries.
- Evaluated the effectiveness of strategies for reducing scarce-fuel consumption in the transportation sector.

- Identified the costs and benefits of measures designed to stabilize the financial condition of U.S. electric utilities.
- Estimated the costs of nuclear reactor shut-downs and evaluated geologic conditions at potential sites for permanent underground storage of nuclear waste.
- Evaluated the cost-effectiveness of environmental regulations, particularly those affecting coal combustion.
- Identified the environmental effects of energy technologies and transportation systems.

EES research and development programs in fiscal 1981 were funded at a level of \$24 million by several federal and state agencies. Our interdisciplinary research staff of over 150 included physical scientists, engineers, economists, and social scientists. Their efforts were closely coordinated with university research and industrial technology development programs. During 1981, EES staff worked with faculty and students from nearly 40 universities and with representatives of more than 400 industries.

We actively promoted industrial participation in our research and development programs, with the goal of increasing private access to EES expertise and obtaining industrial review of our energy technology studies. We also worked with the City of Chicago to establish a metropolitan-area Task Force on High Technology. Our Office of Industrial Marketing Sciences was administratively elevated this year and is now responsible for all Argonne industrial interaction and technology transfer activities.

Energy resources: recovery and use

During 1981, we conducted economic, engineering, and environmental studies of the fossil fuel cycle and selected renewable energy resources. We have evaluated production economics for natural gas recovery and biomass grown as an energy resource, tested new methods of reclaiming coal-mined land, and identified potential health hazards from synfuels technologies. Other studies have focused on the control of adverse environmental impacts from conventional and emerging energy technologies.

Natural gas recovery. Future supplies of natural gas will be drawn increasingly from sources such as tight sands basins and offshore petroleum fields. The natural gas industry estimates that half of the remaining, economically recoverable natural gas in the United States is in tight sands basins. An EES study for the Gas Research Institute examined the production economics and market potential of tight gas. Based on analysis of field data from current tight gas recovery operations, we concluded that extraction costs will be 40-60% higher than earlier studies have projected, primarily because the fracturing techniques used are less effective than anticipated. Despite these higher costs, however, tight gas appears to be economically competitive with other unconventional sources of natural gas.

In support of federal plans to regulate natural gas production on the continental shelf, we developed a reservoir model that can be linked with an economic model to determine optimal production strategies. This computerized modeling package, developed in cooperation with the University of Illinois, is inexpensive to use and allows consideration of physical and economic trade-offs in natural gas recovery.

Reclamation of coal-mined land. We have developed and tested a variety of methods for reclaiming land at abandoned and active coal mines. One study focused on the reclamation use of material dredged from inland waterways, material that usually is stored in impoundment areas that remove land from other uses. In a study for the U.S. Army Corps of Engineers, which maintains shipping lanes in rivers and canals, we demonstrated the economic feasibility and environmental acceptability of using dredged material from the Illinois Waterway to reclaim abandoned surface mines along the waterway. The cost of this approach, which returns land to productive use, was found to be comparable to the cost of conventional disposal of dredged material. Field tests detected no adverse environmental effects from this reclamation technique.



Our advanced computer-controlled GC/MS system provides chemical data useful in process engineering and environmental assessment of new energy technologies.

Midwestern coal deposits often underlie prime farmland, and restoration of agricultural productivity is of concern if these deposits are surface mined. To identify cost-effective means of restoring acceptable crop productivity, we have initiated field and laboratory tests of alternative mine-soil construction techniques and agricultural management options.

Working in cooperation with university researchers and two coal companies, we also have developed new varieties of *Atriplex*, a native woody shrub, for use in revegetating arid western surface mines. These adapted hybrids and varieties have survived the saline, clay environment on mined land better than

any other native plants. This year, at test plots in New Mexico and Utah, we demonstrated the feasibility of economically harvesting commercial quantities of seed from the new varieties.

Performance of flue-gas desulfurization

systems. The increasing use of coal to generate heat and power has brought growing dependence on the flue-gas desulfurization (FGD) technology that often must be employed to comply with sulfur dioxide emission standards. We have examined the technical and economic performance of this still-developing technology.

Argonne recently installed a spray-dryer FGD system at the Laboratory's boiler plant to permit the burning of Illinois-basin coal, rather than oil, to generate steam for the ANL site. EES supervised the process engineering for the installation, which should save Argonne more than \$1 million annually in fuel costs. This effort represents the first use of a spray-dryer FGD system with a high-sulfur coal; this type of scrubber creates fewer waste disposal problems than do the "wet" scrubbers generally used with high-sulfur coal because it produces a dry powder rather than a

sludge. We plan an extensive test program to evaluate the system's performance.

Because the wastewater generated by "wet" FGD systems can contribute to water pollution, the federal government has considered more-stringent effluent standards. One option for meeting such standards would be to recycle wastewater rather than discharge it. We used a laboratory-scale closed-cycle scrubber to study the effects of this approach on the performance of limestone-based FGD systems. The chlorides found in coal concentrate in the recirculating water and decrease sulfur dioxide removal. We found that increased loading of limestone partially offsets this effect but results in higher operating costs.

The "availability" of FGD units — the percentage of time they are actually operational — is known to decrease with increasing sulfur levels in the coal being burned. Based on data from more than 60 operating FGD systems of various designs, we developed the first detailed quantitative description of the relationship between availability and sulfur content. Our results can be used by utilities and industries in determining how to minimize pollution control costs for the type of coal they burn, and have already assisted the

At an abandoned coal mine near Ottawa, Illinois, we covered graded spoil with dredged material and established vegetation, demonstrating the feasibility of this alternative reclamation technique.



Lower Colorado River Authority in Texas in the selection of FGD equipment.

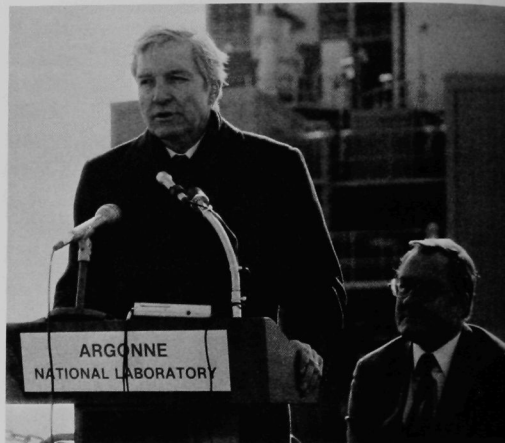
Federal new source performance standards for air pollutants require users of new FGD systems to install one redundant scrubber module, to provide backup sulfur dioxide removal capability. In the case of electric utilities, this extra module enables continued use of power generating units during repair and maintenance of FGD equipment. We devised an analytical technique that can be used to estimate the costs and benefits of redundant FGD modules in specific utility systems. This technique balances the capital, operating, and maintenance costs of extra FGD equipment against the benefits of improved generating-system reliability. Analysis of various types of utility systems indicates that one or, in some cases, two redundant modules are economically justified.

Environmental control for synfuels. EES

laboratory studies have developed an improved understanding of the air and water pollution control issues associated with synfuels production. Employing biological and chemical tests, a multidisciplinary Argonne team found that by-product tar from coal-gasification pilot plants displays both acute and chronic toxicity, including carcinogenesis. EES chemical analysis identified specific polyaromatic amines and hydrocarbons as the causative agents. Our analysis of air samples taken at gasification plants indicated that emitted organic compounds generally concentrate on small dust particles, less than three microns in size, that present a greater potential inhalation hazard than do larger particles. By contrast, most metals were found to concentrate in larger particles.

Using computer-controlled gas chromatographic and mass spectroscopic instrumentation, we devised an advanced analytical scheme for determining the organic-chemical composition of complex air, water, sediment, and oil samples. Because of its speed and low cost, this technique allows construction of large data bases that can reveal cause-and-effect relationships. We have, for example, assembled a data base on the Carnegie-Mellon coal gasifier that can be used to identify correlations between operating conditions and the chemical makeup of process streams and effluents.

Process water from oil shale retorting contains a wide variety of complex organic compounds that have proven difficult to remove using conventional biological treatment methods. We designed a laboratory-scale activated-sludge/powdered-activated-carbon treatment system and tested it in cooperation with Carnegie-Mellon University, using process water



Senator Charles H. Percy and Governor James R. Thompson dedicated Argonne's new flue-gas scrubber in March 1982. Favorable experience with this unit should encourage greater use of Illinois-basin coal by midwestern industries and utilities.

samples from the Occidental Oil Shale Company's Retort #6 in Colorado. Our system provides stable operating conditions under which 90% of the dissolved organic material is removed from the process water; it is the first system reported to attain this level of efficiency.

Ocean thermal energy conversion (OTEC). In

ocean thermal energy conversion, high-performance heat exchangers are used to exploit the temperature difference between surface and deep seawater to drive turbine-generators. Building on experience gained in our tests of OTEC heat exchangers, we planned and directed the operation of two facilities for testing the feasibility of the OTEC concept: the sea-going OTEC-1 platform off Hawaii and the on-shore Seacoast Test Facility at Keahole Point, Hawaii. The 40-megawatt heat exchangers aboard OTEC-1 performed as expected and no appreciable biofouling was detected. At the on-shore facility, however, the biofouling rate has been greater than expected. EES analyses indicate that previously discounted differences in the seawater environment near shore and on

the open sea are the likely cause of the differing results from the two test sites.

The National Oceanic and Atmospheric Administration (NOAA) is responsible for regulation of OTEC facilities. Extending our earlier studies of the physical environmental effects of OTEC water intake and discharge, we developed for NOAA a procedure for screening applications for OTEC plants to identify potential adverse environmental effects, given data on a specific site and proposed plant design. The step-by-step procedure contains concise analyses, based on detailed modeling results, that will allow NOAA to review applications in the 21-day period required by law.

Energy from biomass. In support of federal R&D planning, we explored the resource potential and economics of producing biomass as a source of fuel and chemical feedstocks, with emphasis on production approaches that minimize adverse effects on agriculture. We have, for example, identified some 360 million acres of arable land, not now used to grow food crops, that could support biomass production and determined that more than 50% of this land is being used below its economic potential.

We estimate that biomass has the potential to displace at least 5 quadrillion Btu of energy that would otherwise be supplied by other fuels in the year 2000, with most of the energy coming from woody biomass. Short-rotation forestry, in which relatively dense stands of trees are harvested frequently, is one method for producing woody biomass. Using an EES mathematical model, we have shown that a short-rotation poplar plantation in the Great Lakes region could be profitable at a wood price of \$12 per ton, assuming a 7% discount rate and propagation of 800,000 trees per acre from seedling cuttings sown by broadcasting.

Economical production of ethanol from biomass is constrained by the difficulty of extracting sugar from woody plant material and by yeast's inability to ferment xylose, one of two primary plant monosugars. We have identified and are developing *Fusarium* fungus strains that can break down plant constituents into glucose and xylose and then ferment both sugars. Fermentation of xylose increases the amount of ethanol potentially available from biomass by 40%. Laboratory tests to date have screened 2000 *Fusarium* isolates and mutants and identified more than 60 with the potential to efficiently convert biomass to ethanol. We are seeking *Fusarium* strains and fermentation process conditions that maximize the rate and volume of ethanol production.



Fusarium fungus can perform all the steps needed to obtain ethanol from plant material. We are testing natural *Fusarium* strains and developing mutant strains in an effort to maximize ethanol production.

Energy-efficient technology

We have determined the effectiveness, cost, and environmental effects of advanced technologies, policies, and activities that improve the efficiency of energy use or reduce demand for oil. Our 1981 studies encompassed transportation systems, industrial processes, and advanced energy-supply technologies.

Energy use in transportation. In support of transportation planning by federal, state, and local governments, we have developed detailed forecasts of transportation activity and energy demand. Recent projections indicate that, assuming moderate economic growth and increases in fuel prices, overall travel and freight transport will increase steadily through the year 2000, but improvements in vehicle fuel efficiencies will hold total energy use nearly constant.

Freight movement consumes more than 25% of the energy used in U.S. transportation; we have evaluated conservation options and the response of the freight system to oil shortages. Working with a group of industry experts, we examined the effectiveness of 60 fuel-saving measures for the international maritime industry. This assessment determined that a motivated, well-trained ship crew has the most impact on fuel savings, and increases the effectiveness of nearly all technological and operational measures. As part of an ongoing effort to transfer research results to the private sector, we distributed these findings to 1000 shipping companies.

A study of the effects of various levels of crude oil shortages on the U.S. freight system found that a six-month 14% shortage, a supply interruption significantly more severe than that caused by the Iranian revolution in 1979, would reduce the total tonnage shipped by 12%. We also projected that, as freight rates began to reflect higher fuel costs, shippers' choice of mode would shift in favor of increased fuel efficiency. Results such as these can be used by government and industry in contingency planning efforts.

Electric-vehicle technology and impacts. To assist research and development planners, we conducted market analyses for electric vehicles (EVs). Our studies showed light trucks, vans, and second cars to be the most promising first applications and indicated that Globe-Union's 40 watt-hour/kilogram lead-acid battery, one of the more successful products of the federal EV battery program, provides range and acceleration sufficient to satisfy 25% of the second-car market.

We also projected the effects of EV production on metal availability and costs using our METAL model, which traces international flows of critical resources from mining through final use and identifies the least-cost sources. While moderate EV production levels would have little or no effect on flows of materials used in EV batteries, high production levels — 3 million vehicles per year between 1995 and 2000 —

We evaluated the effectiveness of maritime fuel-saving measures, such as supplementing diesel power with wind power. This oil tanker is equipped with mechanically operated sails that are opened as needed.





A computerized engineering model of district heating systems was used to provide technical assistance to cities considering the construction of such systems.

could bring U.S. dependence on African nations and the Soviet Union as suppliers of nickel.

Industrial energy technologies. Several studies have determined the energy savings and return on investment of industrial cogeneration and waste-heat-recovery systems. Results of such studies support the design of economically and technically optimal systems. Large Rankine-cycle power systems using water as a working fluid and high-temperature heat sources are widely employed to generate electricity in industry. However, such systems become inefficient if low-temperature heat sources, such as industrial waste streams, are used. Our analyses have indicated that smaller (600- to 2400-kilowatt) Rankine-cycle systems using selected organic working fluids and low-temperature waste heat can conserve energy, operate efficiently, and provide acceptable returns on investment.

Benefits of advanced energy-supply systems.

Emerging energy-supply technologies can be incorporated into "community energy systems" that reduce oil and gas consumption. District-heating cogeneration systems that supply homes and businesses with space and water heating are an example of such systems. Using our District Heating Market Potential Model, we projected that district heating cogeneration systems

could reduce scarce fuel consumption by 1.5-1.9 quadrillion Btu annually by the year 2004, depending on the extent to which government removes institutional barriers and provides financial incentives. Such a reduction would be equivalent to 14-17% of 1980 U.S. crude oil imports.

Through a joint program between the Departments of Energy and Housing and Urban Development, we provided analytical assistance to seven cities in Michigan, Missouri, Ohio, Oregon, and Utah that are studying the local feasibility of district heating. For system designs proposed by the cities, we used a computerized engineering model to estimate heat supplies and demands, construction costs, and effects on air pollutant emissions.

Our research has indicated that residential energy use can also be reduced through changes in the design of new developments. Case studies of five neighborhood development projects compared energy usage for conventional site plans and for alternative plans that incorporated energy-saving passive design features, small energy-supply systems such as ground-water heat pumps, and advanced multibuilding energy-supply systems. In the case study of a development in Shenandoah, Georgia, for example, electricity savings of 5-30% and natural gas savings of 30-100% were projected for the alternative plans.

Electric utilities

As measured by standard business indicators, the financial condition of the U.S. electric utility industry has generally deteriorated over the last 15 years, primarily because electric rate regulation provides a lower return on investment than is required by the capital markets. Because the performance of this industry directly affects the nation's energy posture and economic condition, we have analyzed a number of issues central to the financial and technical performance of electric utilities.

Financial performance of utilities. A recent EES analysis indicated that the large (20%) increase in the rate of return on common equity needed to improve the poor financial performance of many utilities can be achieved through a relatively small

(5%) increase in electricity prices. This conclusion was drawn from a case study of a midwestern utility in which the financial impacts of alternative rate-of-return regulations were analyzed under a range of assumptions regarding electricity demand growth, general inflation, and escalation of utility capital and fuel costs.

Costs of oil backout. The abrupt doubling of world oil prices in 1978 and 1979 worsened the financial difficulties of electric utilities that are heavily dependent on oil. Based on a detailed case study of a southeastern utility, we determined that the electricity price increases required to enable utilities to finance conversion and retirement of oil-fired generating units are economically justified from both the utility's and the electric customer's perspectives. Short-term customer losses from price increases were found to be more than offset by customer gains from long-run price decreases.

We also examined the cost-effectiveness of environmental policy alternatives associated with converting oil-fired utility boilers to burn coal. Two regulatory options were compared: application of new source performance standards (NSPS) to converted boilers or exemption of converted boilers from the NSPS with application of emission limits set by state implementation plans (SIPs). Our analysis, based on data for all U.S. utilities, indicated that boiler conversions would slightly reduce total sulfur dioxide emissions under the NSPS approach but would significantly increase those emissions under the SIP approach. The additional cost to utilities per ton of sulfur dioxide removed from stack gases by the NSPS approach, compared to the SIP approach, would range from \$400-600 under favorable economic conditions to as much as \$1600 under less favorable conditions.

EES studies of nuclear and nonnuclear power generation have focused on utility capital and operating costs, energy storage, and nuclear waste disposal.





In analyses conducted in cooperation with six electric utilities, we estimated the costs of hypothetical nuclear reactor shutdowns. Our study used data on Three Mile Island Units 1 and 2 in Pennsylvania (shown here) and on five other nuclear power stations: Browns Ferry in Tennessee, Indian Point in New York, Oconee in South Carolina, Prairie Island in Minnesota, and Zion in Illinois.

Benefits of energy storage. A number of load management options, including customer-owned-and-operated thermal energy storage systems, offer utilities opportunities to build revenues while holding down costs. An EES analysis of the performance and economics of "cool storage" air conditioning systems found that current cool storage technology, installed in commercial buildings under existing electric rate schedules, can pay back the owner's initial investment in three to five years. Our results have encouraged promotion of this technology by Commonwealth Edison in its northern Illinois service area.

Economic effects of nuclear reactor shutdowns. The Nuclear Regulatory Commission asked EES to estimate selected costs associated with shutdowns of electric utility reactors, so that the Commission could balance these and other shutdown costs against the risks of reactor operation when considering safety regulations. Using data on 14 generating units and the six utility systems they supply with electricity, we estimated the cost of replacement energy for hypothetical, long-term reactor shutdowns. The increase in utility operating expenses in the first year

ranged from \$120,000 to \$300,000 per megawatt-year of lost generating capacity, depending on whether the nuclear capacity was replaced by electricity from coal- or oil-fired boilers. The reactors studied had capacities of 570 to 1067 megawatts.

Siting of nuclear waste repositories. The federal government is conducting a long-term study of possible underground sites for permanent storage of high-level radioactive waste, primarily spent fuel rods from nuclear power plants. As part of this effort, EES has initiated a detailed geologic survey of nine north-eastern states and three north-central states to identify the granite formations best suited to house such repositories. The repositories would be located about 3000 feet below ground level.

We will identify 1000-square-mile most-favorable siting areas largely on the basis of seismotectonic criteria; recommended areas will be those expected to be undisturbed by earthquakes, faults, uplift, or subsidence for at least 10,000 years. Our conclusions will be used in conjunction with independent environmental studies of the same areas to select sites meriting further study.

Environment

During 1981, we estimated the costs of alternative air quality policies and evaluated transportation- and energy-related effects on air and water quality. Our results were used by private- and public-sector decision makers concerned with the price of environmental protection and the implications of government regulation of commercial activities.

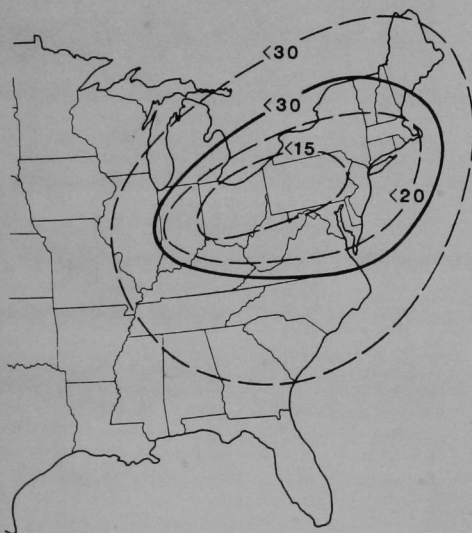
Costs and effects of air quality policies. Proposed revisions to the Clean Air Act include replacing the best available control technology (BACT) requirement for new power plants in prevention-of-significant-deterioration areas with the new source performance standards (NSPS). The BACT requirement typically results in emission limits slightly more stringent than NSPS. We projected and compared emissions and siting constraints with NSPS and with BACT for all coal-fired utility boilers scheduled for construction between 1984 and 2000. The analysis indicated that replacing the BACT provision would save the affected utilities \$1 billion annually; sulfur dioxide emissions would increase by 1.9 million tons per year, or by about 10% of the total 1977 sulfur dioxide emissions from coal-fired utility boilers.

We also estimated the costs and effects of hypothetical strategies for controlling electric-utility emissions of sulfur dioxide, a precursor to the formation of acid rain and atmospheric haze. The regulatory options, applied to coal-burning utilities east of the Mississippi River, included imposition of various emission ceilings and mandatory retrofit installation of flue-gas scrubbers to reduce area-wide emissions.

By 1995, the resulting annual sulfur dioxide emissions from the affected utilities were projected to be 9% to 50% lower than would be expected under current regulations, at an additional annual cost to the utilities of \$0.5 billion to \$4 billion. Some regulatory strategies were found to significantly alter markets for midwestern coals. Both utility costs and effects on local coal industries varied substantially from state to state for any given regulation, indicating the need to consider state-specific factors as well as aggregate regional effects in the development of policies designed to reduce sulfur dioxide emissions.

While the effect of a given sulfur dioxide emission level on the acidity of particular lakes cannot be determined accurately, it is possible to make reasonable estimates of the effect on atmospheric visibility. For

Our projections indicate that a 50% reduction in sulfur dioxide emissions from power plants east of the Mississippi River would reduce atmospheric haze in 1990, as shown on this map. With this emission reduction, there would be no areas in the region studied where visibility would be less than 20 kilometers.



Regional visual range (km)

Summertime 1990

80% Relative humidity

— Before
— After

the regulatory options described above, we analyzed the formation and long-range transport of the fine particulates (those less than 2.5 microns in diameter) that are formed in part from sulfur dioxide and that are the principal cause of atmospheric haze. Results showed that the strategy that lowered annual utility emissions by 50% would also improve regional visibility by nearly 50%.

Another regulatory study estimated the costs of alternative national ambient air quality standards for particulates, using a county-level model that projects emissions and identifies a low-cost attainment strategy for each standard analyzed. We compared costs of the current standard for total suspended particulates (TSP) with those of several possible standards applied only to inhalable particulates less than 10 microns in size. The U.S. EPA is considering dropping primary standards for larger particulates because recent research indicates these particulates do not present a significant health hazard. We estimated the net-present-value attainment cost for the current TSP standard to be \$2 billion, compared to \$0.8 billion for the inhalable standard that appears most likely to be selected by the EPA. While we projected that neither standard would be met in all areas of the country by the statutory attainment dates in the late 1980s, 40% fewer persons would live in nonattainment areas under the inhalable-particulate standard.

Air quality effects of aircraft operation. EES studies have addressed aircraft-related air quality issues using mathematical modeling and field monitoring techniques. In particular, we have examined the contribution of jet engines to atmospheric concentrations of hydrocarbons and nitrogen dioxide. Both pollutants are potential candidates for control by air quality standards, hydrocarbons because of their role in smog formation and nitrogen dioxide because of its toxicity. Jet exhaust samples collected at O'Hare International Airport indicate that the organic portion of the exhaust consists principally of unburned jet fuel, which contains few of the hydrocarbons that are major contributors to smog formation. Our observations and modeling also indicate that aircraft by themselves are not likely to create atmospheric concentrations of nitrogen dioxide in excess of possible standards.



We developed a technique for tracing dredged sand that has been tagged with a dye that is visible under ultraviolet light. Here, an EES scientist prepares sand from the Mississippi River for scanning to detect the dye.

Effects of air pollutants on water quality.

Energy-related processes can contribute to water pollution directly, through aqueous discharges, or indirectly, through deposition of atmospheric emissions. We examined the transport of trace element emissions from utility and industrial coal-fired boilers to surface waters in the Ohio and Missouri river basins, and concluded that such emissions are not likely to significantly increase trace-element concentrations in the two rivers. Our analysis did, however, indicate that certain trace elements — particularly mercury, cadmium, and chromium — emitted from coal-fired utility boilers might create chronic adverse effects in some streams and lakes under worst-case conditions. We have therefore recommended further study of the aquatic effects of trace elements.

Disposal of dredged material.

Sand dredged from river navigation channels by the U.S. Army Corps of Engineers is generally transported to a suitable disposal site on land, often a considerable distance from the dredging operation. Based on field experience in tracing circulation patterns in lakes and streams, EES has provided technical assistance to the Corps in testing a simpler, less expensive disposal technique. We developed a reliable system for tracing the movement of tagged dredged sand after it is dumped in a deep, downstream stretch of a waterway. In tests to date on the Upper Mississippi River, relocated sand has remained in its new location without causing navigational or environmental problems.

International energy development

During 1981 we analyzed energy development alternatives for three industrializing countries: Argentina, the Republic of Korea, and Portugal. This project was conducted in cooperation with, and with the support of, energy planners from each national government. The result was an evaluation of the cost and availability of energy sources and technologies that could best satisfy the specific projected energy demands of each country.

Assessments for Korea and Portugal determined that both countries have the opportunity to diversify

their energy sources to relieve an almost total dependence on oil. Nuclear and coal-fired power generation were found to be economically attractive possibilities. Preliminary results indicate that Argentina's large reserves of natural gas and significant hydroelectric potential could make that country almost energy independent through the year 2000. Appropriate pricing of domestic fuels was identified as a key issue to be addressed by Argentine energy planners.

Energy and Environmental Systems Division**Argonne National Laboratory****Financial Statement**

September 30, 1981

September 30, 1981

BALANCE SHEET (Amounts in \$1000s)

	Areas of Research							Environment and Natural Resources	Other
	Total	Nuclear	Fossil	Solar	Energy Conservation	Energy Storage	Energy Resources		
Assets									
Accounts receivable (note 1)	\$ 8,972	\$ 58	\$ 471	\$ 611	\$ 5,287	\$1,014	—	\$ 1,094	\$ 437
Equipment (note 2)	3,585	—	227	725	317	139	—	1,908	269
Contracted human resources (note 3)	12,564	651	1,602	1,429	2,707	526	46	3,299	2,304
Space (note 4)	10,038	35	524	2,811	1,707	375	11	4,245	330
Total	<u>\$35,159</u>	<u>\$744</u>	<u>\$2,824</u>	<u>\$5,576</u>	<u>\$10,018</u>	<u>\$2,054</u>	<u>\$57</u>	<u>\$10,546</u>	<u>\$3,340</u>
Liabilities and Accumulated Resources									
Accrued expenses	\$ 8,972	\$ 58	\$ 471	\$ 611	\$ 5,287	\$1,014	—	\$ 1,094	\$ 437
Accumulated resources (note 5)	26,187	686	2,353	4,965	4,731	1,040	57	9,452	2,903
Total	<u>\$35,159</u>	<u>\$744</u>	<u>\$2,824</u>	<u>\$5,576</u>	<u>\$10,018</u>	<u>\$2,054</u>	<u>\$57</u>	<u>\$10,546</u>	<u>\$3,340</u>

See accompanying notes to financial statements.

Notes to Financial Statements (amounts in \$1000s)**1. Summary**

The Energy and Environmental Systems Division (EES) of Argonne National Laboratory is an applied science and engineering organization that specializes in systems analysis, planning, policy evaluation, and technology development. Argonne National Laboratory is operated under a contract among the U.S. Department of Energy, the University of Chicago, and the Argonne Universities Association, a consortium of 30 universities.

The Statement of Operations is intended to summarize the activities that have taken place within EES during the fiscal year ended September 30, 1981. The Balance Sheet represents management's estimate of the current value of the research resources available to the Division as of September 30, 1981. Revenue, expense, assets and liabilities are displayed by area of research.

A summary of significant accounting policies follows:

A. Cash

Cash balances are not reflected in EES because all cash management functions are performed by Argonne National Laboratory on behalf of EES.

B. Accounts Receivable/Accrued Expense

At the end of each fiscal year, EES has received and utilized on projects certain goods and services that have not been invoiced by the suppliers. The expense and related income are shown in the Statement of Operations.

Therefore, the associated accrued expenses and

receivables are reflected at the Division-level Balance Sheet.

C. Depreciation

Equipment and building purchases are expensed at the time of acquisition. Therefore, no provision for depreciation is recorded in the Statement of Operations. The equipment and building inventories are valued annually for the Balance Sheet (see notes 2 and 4) as of the end of the fiscal year.

D. Revenue Recognition

EES is primarily funded by the Department of Energy (DOE) for research projects. These projects are generally submitted by the Division for DOE approval. Items considered by DOE in the approval process include an evaluation of potential contribution toward national research goals, cost-effectiveness, and the merits of similar proposals received by DOE. Revenue in amount equal to expense is recognized by EES at the time reimbursable expenses from research activities are incurred. The areas of research listed in the financial statements reflect the organization of the Department of Energy as of September 30, 1981.

2. Equipment

Equipment is valued using the general price level adjusted historical cost method. Had equipment been valued at historical cost, the value would have been \$2,842.

STATEMENT OF OPERATIONS (Amounts in \$1000s)

September 30, 1981

	Areas of Research								Other
	Total	Nuclear	Fossil	Solar	Energy Conservation	Energy Storage	Energy Resources	Environment and Natural Resources	
Revenue									
DOE	\$31,914	\$318	\$2,192	\$5,950	\$12,724	\$2,634	\$26	\$7,008	\$1,062
Other federal	742	155	275	166	92	—	—	—	54
State	61	—	—	—	—	—	—	61	—
Private	83	—	69	—	—	—	—	—	14
Total	<u>\$32,800</u>	<u>\$473</u>	<u>\$2,536</u>	<u>\$6,116</u>	<u>\$12,816</u>	<u>\$2,634</u>	<u>\$26</u>	<u>\$7,069</u>	<u>\$1,130</u>
Expenditures									
Direct Project Cost									
Effort related	\$ 9,113	\$228	\$ 978	\$1,629	\$ 2,525	\$ 618	\$17	\$2,576	\$ 542
Materials and services	6,698	100	619	953	2,637	697	—	1,461	231
Equipment	436	13	96	(18)	26	27	—	292	—
Major procurements (note 6)	11,158	8	269	2,567	6,120	908	—	1,252	34
Other	185	11	19	33	34	40	—	42	6
Subtotal	<u>\$27,590</u>	<u>\$360</u>	<u>\$1,981</u>	<u>\$5,164</u>	<u>\$11,342</u>	<u>\$2,290</u>	<u>\$17</u>	<u>\$5,623</u>	<u>\$ 813</u>
Indirect Project Cost									
Division	\$ 2,355	\$ 51	\$ 251	\$ 431	\$ 665	\$ 155	\$ 4	\$ 654	\$ 144
ANL	2,855	62	304	521	809	189	5	792	173
Subtotal	5,210	113	555	952	1,474	344	9	1,446	317
Total	<u>\$32,800</u>	<u>\$473</u>	<u>\$2,536</u>	<u>\$6,116</u>	<u>\$12,816</u>	<u>\$2,634</u>	<u>\$26</u>	<u>\$7,069</u>	<u>\$1,130</u>

See accompanying notes to financial statements.

A summary of equipment valued at adjusted historical cost follows:

Computer associated	\$ 773
Research and other	2,812
Total	<u>\$3,585</u>

3. Contracted Human Resources

Human resources are valued using opportunity cost as a measure of their economic value. The opportunity cost is established by the competitive bidding process through which research contracts are awarded. The effort costs contained within a contract represent the most cost-effective alternative available to the sponsor at the time the contract was awarded. The sum of the effort costs for all current authorized research projects equals the total human resource value of EES.

During periods of rapid change in the total amount of EES research activity, there may be a period of adjustment before actual staffing levels coincide with the levels mandated by awarded contracts. This adjustment period is a contract backlog of human resource potential. The human resources valuation method used in these statements excludes the backlog

by showing on the Balance Sheet only those contracted effort costs attributable to persons employed at the end of the fiscal year.

4. Space

Space is valued at replacement cost using the current replacement cost method. Cost is assigned to research areas based on the prorated share of total floor space. The total estimated replacement cost on September 30, 1981, is \$10,038. Any change in the total value from one year to the next is added to or subtracted from accumulated resources in the Balance Sheet.

Had the buildings and facilities used by EES been capitalized on the dates they were occupied, it is estimated their cost would have been \$6,275.

5. Accumulated Resources

Accumulated resources represent the sum of the estimated values of space, equipment, and contracted human resources available to EES.

6. Major Procurements

Major procurements are contracts between EES and third parties with a value of \$25.0 or more.

Recent publications

The documents listed here were published between January 1, 1981, and March 1, 1982. A more comprehensive bibliography of all EES publications since 1968 is available upon request. Our technical reports may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

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